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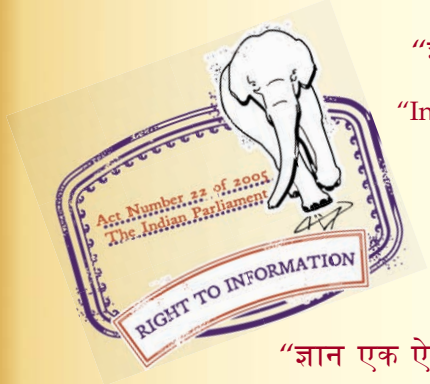

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"Knowledge is such a treasure which cannot be stolen"

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IS : 11548 - 1986
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Indian Standard

SPECIFICATION FOR CAPACITORS FOR SURGE PROTECTION FOR USE IN VOLTAGE SYSTEM ABOVE 650 V AND UP TO 33 KV

UDC 621·319·4 : 621·316·93

INDIAN STANDARDS INSTITUTION
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Gr 5

November 1986

Indian Standard

SPECIFICATION FOR CAPACITORS FOR SURGE PROTECTION FOR USE IN VOLTAGE SYSTEM ABOVE 650 V AND UP TO 33 KV

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Indian Standard

SPECIFICATION FOR CAPACITORS FOR SURGE PROTECTION FOR USE IN VOLTAGE SYSTEM ABOVE 650 V AND UP TO 33 KV

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 28 January 1986, after the draft finalized by the Power Capacitor Sectional Committee had been approved by the Electrotechnical Division Council.

0.2 This standard has been prepared with a view to formulate the safety, performance requirements and methods of tests for capacitors connected in parallel to an electrical equipment or a power system for the purpose of surge protection. This standard also provides guidance for installation and operation of such capacitors.

0.3 The capacitors for surge protection are intended for use in parallel with independent lightning arrestors or similar surge limiting apparatus of proper rating. The surge capacitors in conjuction with surge arrestors or lightning arrestors are also used to protect the insulation of rotating machines (motors and generators) and transformers from the on slaught of surges both from steepness of wave front and the magnitude of surge level. The capacitors for surge protection are intended to slope down the travelling wave, thus reducing the effect of steep rate of rise of surge on the insulation.

0.4 The requirements of shunt capacitors for power factor improvement are covered in IS : 2834-1986*. Taking into consideration the similarity in requirements and tests, a reference is made to IS : 2834-1986* wherever appropriate.

0.5 In preparing this standard considerable assistance has also been derived from IEC Doc: 33 (Central Office) 70 'Shunt capacitors for ac power system having a rated voltage above 660 V', issued by the International Electrotechnical Commission (IEC).

*Specification for shunt capacitors for power systems (*second revision*).

0.6 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This specification applies to capacitor units and assembly of capacitor units with accessories to form complete capacitor equipment for surge protection of equipment for medium and high voltage power systems up to 33 kV generally having a frequency of up to and including 100 Hz.

1.2 This standard does not cover the following types of capacitors:

a) Small ac capacitors as used for fluorescent and discharge lamps and for electric sign circuits (*see* IS : 1569-1976†);

b) Shunt capacitors for power systems (*see* IS : 2834-1986‡);

c) Capacitors for motor starting applications and the like (*see* IS : 2993-1975§);

d) Radio interference suppression and filter capacitors (*see* IS : 3723‖).

e) Capacitors intended for control, protection and measurement purposes (for example, coupling capacitors and the like) (*see* IS : 9348-1979¶);

f) Series capacitors (*see* IS : 9835-1981**); and

g) Energy storage capacitors.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions, in addition to those given in IS : 1885 (Part 42)-1986††, shall apply.

*Rules for rounding off numerical values (*revised*).

†Specification for capacitors for use in tubular fluorescent, high pressure mercury and low pressure sodium vapour discharge lamp circuits (*first revision*).

‡Specification for shunt capacitors for power systems (*second revision*).

§Specification for motor capacitors (*first revision*).

‖Specification for capacitors for radio interference suppression.

¶Specification for coupling capacitor and capacitor divider.

**Specification for series capacitors for power systems.

††Electrotechnical vocabulary: Part 42 Power capacitors (*first revision*).

2.1 Type Tests — Tests carried out to prove conformity to the specification. These are intended to prove the general qualities and design of a given type of capacitor.

2.2 Acceptance Tests — Tests carried out on samples selected from a lot for the purpose of varifying the acceptability of the lot.

2.2.1 *Lot* — All capacitors of the same type, design and rating, manufactured by the same factory during the same period, using the same process and materials, offered for inspection at a time shall constitute a lot.

2.3 Routine Tests — Tests carried out by the manufacturer on each capacitor to check requirements which are likely to vary during production.

3. RATINGS

3.1 Rated Outputs — The preferred rated outputs of capacitors for surge protection for upper temperature category of 45°C shall be as follows:

Highest System Voltage kV	*Surge Capacitor Voltage Rating (Single Phase Rating)* kV	*Capacitance Per Phase* μF
3·6	6	0·5 and 0·5
7·2	12	0·25 and 0·5
12	18	0·25 and 0·5
24	28	0·25
36	40	0·125 and 0·25

NOTE — For temperature categories other than 45°C and other voltage ratings, the rated output of capacitor shall be as agreed to between the manufacturer and the user.

3.2 Rated Voltage — The rated voltage of the capacitor for surge protection shall be as specified in IS : 585-1962*.

3.3 Rated Frequency — The standard frequency for the purpose of this specification shall be 50 Hz.

NOTE — If a frequency higher or lower than that stated above is specified by the purchaser, it does not preclude compliance with this standard. In such a case corresponding changes, where necessary, shall be taken into account as indicated in their respective places.

*Specification for voltages and frequency for ac transmission and distribution systems (*revised*).

3.4 Spark Over Voltage — The spark over voltages of the protective equipment used in the system shall be as follows:

Highest System Voltage	*Lightning Arrester Rating (see* IS:3070)	*Maximum Impulse Spark Over Voltage for Lightning Arrester*	*Rated Surge Voltage*	*Impulse Test Voltage for Capacitor*
kV	kV	kV	kV	kV
(1)	(2)	(3)	(4)	(5)
3·6	3	12	6	55
7·2	6	21	12	75
12	9;12;15	32;42;51	18	100
24	21;24	68;77	28	140
36	30;36;39	97;116;126	40	190

4. SERVICE CONDITIONS

4.1 Ambient Temperatures — Capacitors shall be suitable for operation at any of the temperature categories given in **4.1** of IS : 2834-1986*.

4.2 Altitude — Unless otherwise specified, capacitors shall be suitable for operation on sites at altitudes up to and including 1000 metres above mean sea level.

5. PERMISSIBLE OVERLOADS

5.1 For the capacitors covered by this standard, the maximum permissible overloads shall not exceed any one of the limits given here in **5.2** and **5.3** and calculated according to Appendix A of IS : 2834-1986*.

5.2 Voltage — Capacitor shall be suitable for continuous operation at an rms voltage between terminals not exceeding 1·10 times the corresponding rated line voltage and including transients.

5.3 Current — Capacitor shall be suitable for continuous operation at an rms line current not exceeding 1·30 times the current which occurs at rated sinusoidal voltage and rated frequency including transients.

5.4 Reactive Output — The maximum continuous reactive output of a capacitor (including due to the flow of harmonic currents) (*see* Appendix A of IS : 2834-1986*) shall not exceed 30 percent over the rated reactive output of the capacitor.

*Specification for shunt capacitors for power systems (*second revision*).

5.5 Impulse Voltages — The maximum impulse voltage which the capacitor shall withstand are as follows:

Rating of the Capacitor for Surge Protection	*Peak of 1·2/50 microsecond Wave*
kV	kV
(1)	(2)
6	55
12	75
18	100
28	140
40	190

6. SAFETY REQUIREMENTS

6.1 Capacitor equipment shall be provided with a directly connected discharge device.

6.1.1 This discharge device shall reduce the residual voltage from the crest value of the rated voltage V_n to 50 volts or less within five minutes after the capacitor is disconnected from the source of supply.

6.1.2 A discharge device is not a substitute for short-circuiting the capacitor terminals together to earth before handling.

NOTE — A residual charge may sometimes be left on the interconnections of series connected capacitors due to blown fuses, interrupted internal connections, or non-linear behaviour of the dielectric resulting from over-stressing. These interconnections, therefore, shall be shortcircuited to earth before handling.

6.2 Earth Connection — The metal container of the capacitor shall have an earthing terminal clearly marked with symbol ⏚ .

a) The minimum short circuit current density in copper for these connections, shall be 165 A/mm^2 with a time rating of 1 second.

b) Total resistance of the earthing connection at all times shall confirm with the value laid down in Indian Electricity Rules, 1956.

c) Each surge-capacitor and lightning arrester installation shall have an independent earthing station of its own. It shall not depend exclusively on a common earthing system.

NOTE — The earthing connection throughout shall have a minimum cross-section capable of grounding the full short circuit level energy of the system to ground without raising the earthed point potential anywhere above 50 volt momentarily.

6.3 Other Safety Requirements — Capacitors shall comply with the relevant general safety regulations for power installations as prescribed under Indian Electricity Rules, 1956.

7. GUIDE FOR INSTALLATION AND OPERATION OF CAPACITORS FOR SURGE PROTECTION

7.1 A general guidance for proper installation and operation of the surge capacitors is given in Appendix A.

8. MARKING

8.1 Rating Plate

8.1.1 The following information shall be given on the rating plate of each capacitor unit (except as provided in the Note):

a) Reference to this Indian Standard : as ref ISS 11548,
b) Manufacturer's name or trade-mark,
c) Manufacturer's identification number,
d) Rated output in microfarads,
e) Rated voltage,
f) Rated current,
g) Rated frequeney,
h) Upper limit of temperature category,
j) Number of phases,
k) Connection symbol,
m) Insulation level,
n) Discharge device, and
p) Total weight.

NOTE 1 — Further information which is of importance for the safety of persons or equipment, shall be stated either on the rating plate or in an instruction sheet. In the latter case the rating plate shall bear a reference to this instruction sheet.

NOTE 2 — A warning instruction that 'DISCHARGE CAPACITORS BEFORE HANDLING' should be prominently marked in red.

NOTE 3 — Capacitor banks shall be provided with a rating plate so attached as to be visible from the exterior of the housing or enclosure of the bank. It shall include items given in **8.1.1** as relevant to the rating of complete bank.

8.1.2 The type of connection shall be indicated by the following symbols:

$\triangle$: Delta

λ : Star

$\not\lambda$: Star neutral broughtout.

||| : Three sections without internal inter-connections. For 3-phase units, the total output shall be given.

8.1.3 The insulation level shall be marked by means of two numbers separated by a stroke, the first number giving the rms value of the power-frequency test voltage in kV and the second number giving the crest value of the impulse test voltage in kV peak (for example, 28/75).

8.2 The capacitors may also be marked with the ISI Certification Mark.

NOTE — The use of the ISI Certification Mark is governed by the provisions of the Indian Standards Institution (Certification Marks) Act and the Rules and Regulations made thereunder. The ISI Mark on products covered by an Indian Standard conveys the assurance that they have been produced to comply with the requirements of that standard under a well-defined system of inspection, testing and quality control which is devised and supervised by ISI and operated by the producer. ISI marked products are also continuously checked by ISI for conformity to that standard as a further safeguard. Details of conditions under which a licence for the use of the ISI Certification Mark may be granted to manufacturers or processors, may be obtained from the Indian Standards Institution.

8.3 Terminal Markings

8.3.1 The terminals of the three-phase capacitors for surge protection shall be marked as *A*, *B*, *C* and *N* representing the three phases and neutral.

9. TESTS

9.0 General — Unless otherwise specified, the standard ambient temperature range shall be 15° to 35°C. If corrections have to be made, the reference temperature shall be 27 ± 2°C.

9.1 Classification of Tests

9.1.1 *Type Tests* — The following shall constitute type tests:

a) Measurement of capacitance (*see* **9.2**),
b) Thermal stability test (*see* **9.3**),
c) Dielectric loss angle test and capacitor losses test (*see* **9.4**),
d) Voltage tests (*see* **9.5**),
e) Impulse voltage test (*see* **9.6**),
f) Partial discharge test (*see* **9.12**),
g) Short circuit discharge test (*see* **9.7**),
h) Test for internal discharge device (*see* **9.8**),
j) Sealing test (*see* **9.9**),
k) Verification of container protection against corrosion (*see* **9.10**), and
m) Drop-hammer test for bushing seal (*see* **9.11**).

9.1.1.1 *Criteria for approval* — One sample shall be submitted for testing together with the relevant data of the capacitor. The testing authority shall issue a certificate if the capacitor for surge protection is found to comply with the tests given in **9.1.1**.

NOTE — A separate sample may be used for carrying out partial discharge test.

If any of the sample fails in relevant type tests, the testing authority may call for fresh samples, not exceeding twice the original number and subject them again to tests in which failure occurred. If in repeat tests no failure occurs, this test may be considered to have been satisfactory.

9.1.2 *Acceptance Tests* — The following shall constitute the acceptance tests:

a) Measurement of capacitance (*see* **9.2**),
b) Dielectric loss angle test and capacitor losses test (*see* **9.4**),
c) Voltage tests (*see* **9.5**),
d) Test of internal discharge device (*see* **9.8**), and
e) Sealing test (*see* **9.9**).

9.1.2.1 *Sampling plan and criteria for acceptance* — The number of pieces of capacitors for acceptance test may be agreed upon between the purchaser and the manufacturer. The recommended sampling plan for capacitors for surge protection is given in Appendix B.

9.1.3 *Routine Tests* — The following shall constitute routine tests:

a) Measurement of capacitance (*see* **9.2**),
b) Dielectric loss angle test and capacitor losses test (*see* **9.4**),
c) Voltage test (*see* **9.5**),
d) Test for internal discharge device (*see* **9.8**), and
e) Sealing test (*see* **9.9**).

9.2 Measurement of Capacitance

9.2.1 The capacitance shall be measured using a method which excludes errors due to harmonics and accessories such as resistors, reactors and blocking circuits. The standard conditions for the test shall be a voltage between 0·9 and 1·1 times the rated voltage and a frequency between 40 and 60 Hz.

Measurement at lower voltages and rated frequency may be made by agreement between the manufacturer and the purchaser.

9.2.2 *Requirement* — The total output computed from the measured capacitance at the rated voltage and the rated frequency shall not differ by more than:

a) $^{-5}_{+10}$ percent of specified value of the unit for single capacitor units for making capacitor banks, and

b) $^{-0}_{+10}$ percent of the rated value for capacitor banks.

9.3 Thermal Stability Test

9.3.1 This test is intended to demonstrate the thermal stability of capacitor units under cooling and electrical conditions in **9.3.2** and **9.3.3.**

9.3.2 *Cooling Conditions* — The air-cooled self ventilated capacitors shall be placed in an enclosure where the cooling air temperature is at the upper limit as stated on the rating plate. Throughout the test the cooling air temperature shall be checked by means of a thermometer lagged so as to have a thermal time constant of approximately 1 hour. During the whole test, the difference between the measured cooling air temperature and the specified test temperature shall not exceed 2°C.

9.3.3 *Electrical Conditions* — The capacitor shall be subjected to a voltage at rated frequency and of substantially sinusoidal form of 1·2 times the rated voltage for a period of 48 hours.

9.3.3.1 The total test period for the self ventilated unit shall be 48 hours. The final period of test during which the capacitor shall be in equilibrium shall be 8 hours.

9.3.3.2 During the final period of test, the capacitor losses or the temperature of the capacitor container near the top shall be measured every 2 hours.

9.3.3.3 Throughout this period, the change in temperature at maximum body temperature spot shall not be more than 1°C. Where tan δ measurement is possible, it shall not vary by more than $\pm 1 \times 10^{-4}$. The sensitivity of measurement shall not be worse than $\pm 10^{-4}$.

If greater change is observed, the test shall be continued until either equilibrium or breakdown occurs.

9.3.3.4 The capacitance measured after the test, related to the same temperature of dielectric shall not differ by more than 2 percent from capacitance measured before the test.

9.4 Dielectric Loss Test and Capacitor Losses Test

9.4.1 *Dielectric Loss Angle* — The dielectric loss angle test shall be conducted as specified in **14** of IS : 2834-1986*. It shall be in accordance with best capacitor manufacturing practices for various types of liquid dielectrics used.

The value of the tangent of the dielectric loss angle determined by test shall not exceed by more than 10 percent of the value agreed to between the manufacturer and the purchaser.

9.4.2 *Test for Capacitor Losses* — The capacitor losses shall normally be determined by direct measurements on the complete

*Specification for shunt capacitors for power systems (*second revision*).

capacitor including discharge devices, using the method given in **9.4.1**. The losses may, however, be calculated from the measurement of the dielectric loss angle (*see* **9.4.1**) by adding to it all I^2R losses in conductors and discharge devices. The value of the capacitor losses shall be expressed in watts and shall be subject to a tolerance of + 10 percent on the value agreed to between the manufacturer and the purchaser.

9.5 Voltage Test — All capacitors shall withstand without detriment, the test voltage appropriate to the rating of the capacitor. The test shall be made using an alternating supply at a frequency between 40 to 60 Hz and the voltage wave shall be sufficiently free from harmonics to ensure that, when applied to the capacitor, the resulting current shall not exceed the value corresponding to a sinusoidal wave by more than 10 percent.

Discharge device may, if desired, be disconnected during these tests.

9.5.1 *Test Between Terminals* — Every capacitor shall be subjected for 10 seconds to either test (a) or test (b) as given in **16.1** of IS : 2834-1986*.

9.5.2 *Test Between Line Terminals and Container* — An ac test voltage of the value specified in col 2 of table under **9.6.2** shall be applied between the terminals (short-circuited) of each capacitor unit and its container, and maintained for a period of one minute, except that when one terminal of the capacitor is connected to the container, the test specified in **9.5.1** shall suffice.

9.6 Impulse Voltage Test

9.6.1 This test is intended to determine the ability of capacitor unit to withstand surge voltages. The test shall be carried out across the terminals in case of all insulated terminals with body at earth potential or across a terminal and body where body forms the second terminal.

9.6.2 The crest value of impulse shall correspond to the insulation level of the capacitor as given below:

Rating of Capacitor for Surge Protection kV (rms)	*Power Frequency Test Voltage* kV (rms)	*Impulse Test Voltage*† (1·2/50 μs) kV (peak)
(1)	(2)	(3)
6	20	55
12	28	75
18	39	100
28	48	140
40	72	190

*Specification for shunt capacitors for power system (*second revision*).

†Wave form of the applied impulse shall be standard impulse wave but the front time may be increased to a maximum of 5 μs after agreement between the manufacturer and the purchaser. Five impulses of each polarity shall be applied.

9.6.2.1 If more than one flashover occurs, the capacitor shall be deemed as not having passed the test. If one flashover occurs in a series of five impulses of the same polarity, ten additional impulses of the same polarity shall be applied and there shall be no further flashover by any of these impulses.

9.7 Short-Circuit Discharge Test — The unit shall be charged by means of dc and then discharged through a gap situated as close as possible to the capacitor. It shall be subjected to five such discharges within 10 minutes.

The test voltage shall be equal to 2·5 Um.

Within five minutes after this test, the unit shall be subjected to a voltage test (*see* **9.5**).

The capacitance shall be measured before the discharge test and after the voltage test. The two values shall not differ by more than 2 percent.

9.8 Test for Internal Discharge Device — A test for verifying the requirements of discharge devices as given in **6.1.1** shall be made. Methods of test for efficacy of discharge devices are given in Appendix G of IS : 2834-1986*.

9.9 Sealing Test — Un-energized capacitor units shall be heated throughout so that all parts reach a temperature of T_{max} + 10°C where T_{max}, is either the maximum temperature given on the name plate or the maximum temperature achieved during thermal stability test or 65°C, whichever is higher. This temperature shall be maintained for one hour. No oil leakage shall occur.

A suitable indicator to indicate leakage of oil shall be used.

9.10 Verification of Container Protection Against Corrosion — At the request of the purchaser, the manufacturer shall provide a report of the performance of measures taken against corrosion of the unit when being used under specified atmospheric conditions. Data on sequence of protective films with their thickness shall be given. This shall correspond with the requirements in relevant standards given below:

IS : 3618-1966†	For phosphatising
IS : 5666-1970‡	For primer coats
IS : 101-1964§	For enamel paints
IS : 8629 (Parts 1 to 3)-1977‖	For protective metal deposits

*Specification for shunt capacitors for power systems (*second revision*).

†Specification for phosphate treatment of iron and steel for protection against corrosion.

‡Specification for each (pretreatment) primer.

§Methods of test for ready mixed paints and enamels (*second revision*).

‖Code of practice for protection of iron and steel structures from atmospheric corrosion.

9.11 Drop Hammer Test for Bushing to Body Seal — A round metallic ball with a rubber coating of at least 6 mm around, with the rubber hardness between A 50 and A 60 Shore hardness and with a total weight equal to the weight of the porcelain bushing (along with its detachable metal parts) shall be used as a hammer.

9.11.1 The unit shall be positioned on its side with the bushing extending in a cantilever type horizontally. The metallic ball with the rubber coating shall be dropped from a height of 1·5 metres so that it strikes the porcelain roughly in its centre length, without obstruction. One test shall be carried out with each side of the container resting on ground alternatively, that is, 4 tests per bushing in all.

9.11.2 Sealing test (*see* **9.9**) shall be carried out after this test. There shall be no leakage of oil.

9.12 Partial Discharge Test

9.12.1 *Test Specimen for Partial Discharge* — With the use of series sections in high capacitance specimen, the excessive inductance will serve to reduce detection sensitivity. To avoid the possibility of substential errors in measurements, loss in sensitivity and deterioration in response characteristics, test will be carried out on reprosentative samples of the capacitor dielectric system specimens designed for the same stress which have the following characteristics:

Capacitance	0·5 microfarad or less
Sealed container	
Internal pressure,	1 atmosphere
No internal series connected sections	

9.12.2 The test voltages applied during this test shall be substantially sinusoidal at approximately the rated frequency of the capacitor. The test circuit shall be suitably damped to reduce overvoltages due to transients as much as possible. Throughout the test, the ambient air temperature shall be 25 $\pm$10°C.

9.12.3 The rated voltage shall be applied to the capacitor for sufficient time to ensure that it reaches thermal equilibrium. Then a test voltage of 2 V_n shall be applied once only to the capacitor for one second.

9.12.4 The voltage shall then be reduced to 1·2 V_n and maintained for a period of 10 min, after which voltage shall be raised to 1·5 V_n and maintained for a period of 10 min. At no time during this latter 10 minute period shall an increase in ionization level be observed.

9.12.5 Before and after the test, the capacitance in both cases shall be measured in accordance with **9.2** under identical conditions. The change of capacitance shall not exceed 2 percent when measured at 27 $\pm$ 5°C.

9.12.6 When interpreting the results of these measurements two factors shall be taken into account:

a) The reproducibility of the measurement; and

b) The fact that an internal change in the dielectric may cause a small change of capacitance without breakdown of any element of the capacitor.

NOTE 1 — The value of the test voltage for 1 second (*see* **9.12.3**) has been chosen taking into consideration the service condition of the capacitor and especially the over voltages including switching surges liable to occur in the net-work in which the capacitor is installed.

NOTE 2 — This test must be made in accordance with the above test cycle, without switching off the voltage.

NOTE 3 — The measurement of ionization level may be insensitive if the capacitance of the unit to be tested is too large in relation to that for which the test apparatus has adequate sensitivity. In this case agreement should be reached between the manufacturer and the purchaser to the test being carried out on a model unit of a smaller capacitance, but of the same design and construction as that being supplied.

NOTE 4 — The term 'partial discharge' as used herein refers to discharges generated in the dielectric and is equivalent to the term 'ionization'.

NOTE 5 — Such test methods as the measurement of tan δ are not considered adequate for detection of partial discharge. General requirements concerning partial discharge measurements are given in Appendix C.

10. EFFECTIVENESS OF LIGHTNING ARRESTORS USED IN CONJUNCTION WITH SURGE CAPACITORS

10.1 The guidance on the effectiveness of lightning arrestors used in conjunction with the surge capacitors is given in Appendix D.

APPENDIX A

(*Clause* 7.1)

GUIDE FOR INSTALLATION AND OPERATION OF CAPACITORS FOR SURGE PROTECTION

A-1. GENERAL

A-1.1 Unlike most electrical apparatus, surge capacitors operate continuously during service. They are subject to voltage variations as well as line surges arising out of various causes, such as lightning, switching, etc.

A-1.2 The steady state voltage stresses on these capacitors are downgraded. However, the frequent voltage/current surges (both peak values

and the numbers absorbed) control the capacitor life. Therefore it is recommended to monitor this parameter where feasible.

A-1.3 These capacitors have been standardized around two/three values only, namely, 0·25, 0·50, 0·125 mfd. Their effect on amplification of harmonics, over voltages due to switching, unsatisfactory working of audio frequency remote control apparatus could be neglected.

However when these are used to protect low capacity isolated generators (below 250 kVA, 3·3 kV) proper consideration may be given to the possibility of boosted excitation and run away voltages likely to be generated under light load conditions.

A-2. OPERATING TEMPERATURES

A-2.1 Because of the down grading of voltage stresses, the actual operating temperatures are not expected to rise significantly over the ambient. As such no special efforts towards cooling are recommended.

The maximum value of the cooling air temperature, as a general rule, should not exceed by more than 5°C, the ambient temperature, for the appropriate category.

A-2.2 These capacitors are likely to be placed in closed cabinets in a generating station or they could be located out in the yard under the open.

a) The ventilation of the operating room as well as with the cabinet in which these capacitors are enclosed, shall provide good air circulation around each unit.

b) The temperature of capacitors subjected to radiation from the sun or from any surface at a high temperature will increase. Depending on the cooling air temperature, the intensity of the cooling and the intensity and duration of the radiation, it may be necessary to choose one of the following remedies:

   i) To protect the capacitors from radiation, and

   ii) To choose capacitor designed for a higher upper limit of temperature category or which is otherwise suitably designed.

A-2.3 Capacitors for 45°C are suitable for most of the applications under tropical conditions. In some locations. however, the ambient temperature may be such that a capacitor for 50°C is required. The latter may also be needed for those cases where the capacitors are frequently subjected to the radiation of the sun during several hours (for example, in desert territories), even though the ambient temperature is not excessive [*see* **A-2.2** (b)].

In exceptional cases, the ambient temperature may be higher than 50°C maximum or 45°C daily average, and where it is impossible to improve the cooling conditions, capacitors of a special design or having a higher rated voltage should be used.

A-2.4 Repeated absorption of surges can cause ionization, gas liberation and subsequent deterioration of capacitor life. A capacitor which has deteriorated in this fashion is characterized by:

a) random noises emitted from within; and

b) higher temperature rises.

When this is observed, the capacitor should be immediately replaced. If this happens too frequently, substituting the replacement with a next high voltage level may be considered. The lightning arrestor also needs careful monitoring in this case.

A-2.5 Quite often, the surge capacitors are connected in parallel with generator windings and their earthings are connected through very sensitive relays so that the system will trip, should a generator winding show signs of deterioration and resultant unbalance in the earth currents.

In such cases, the surge capacitors must be accurately matched in values between all the three phases. Matching within ± 2 percent is recommended.

A-2.6 Should a surge capacitor leak/seep/weep, it should be immediately attended to. If a live part within a surge capacitor gets exposed (out of oil) due to oil level going down, it will spark across upon absorbing a surge and explode. This can lead to serious accidents in close proximity to a very costly generator. Therefore, leaks must receive special attention. Upon spotting a leak, the soldered seal on the capacitor may be desoldered, oil level may be made up with degassed oil [obtained from the capacitor manufacturer, the leak may be sealed by soldering and/or with the help of epoxy and finally the solder seal may be soldered back.

A-2.7 Whenever a generator has tripped due to whatsoever reasons, and it is being restarted again, the surge capacitors may be rechecked before doing so:

a) Insulation of each unit may be measured with a 2 000 volts meggar and insulation values may be compared with the original values.

b) All three units may be connected across a three-phase, 400 volts supply and the balance between currents as well as individual output currents may be taken. These are then compared with the original values.

Upon detection of internal damage, the surge capacitors may be immediately replaced.

A-3. SPECIAL CONDITIONS

A-3.1 Apart from high ambient temperature, other adverse conditions of use are liable to be met within tropical countries. Where the purchaser knows that such conditions are present, the manufacturer should be informed when the capacitors are ordered. This information should be given to the suppliers of all associated equipment for the capacitors installation.

The most important conditions are the following:

a) Frequent occurrence of periods of high relative humidity. It may be necessary to choose equipment for a higher insulation level, or to use insulators of special design. Attention is drawn to the possibility of Lightning Arrestors being shunted by a deposit of moisture on their surface.

b) Rapid mould growth — Metals, ceramic materials and some paints and lacquers do not support mould growth. Fungicidal materials do not retain their poisoning property for more than several months and, therefore, mould may develop in an installation on places where dust, etc, can settle.

c) Corrosive atmosphere which is found in industrial and coastal areas. It should be noted that in higher temperature the effects of such atmospheres may be more severe than in temperate climates.

d) Attack by insects.

A-4. OVER VOLTAGE AND OVER CURRENT LOADING

A-4.1 The capacitor ratings are chosen with respect to striking/quenching voltages of the lightning arrestors. Consequently they are much higher than the system voltages. Therefore, they can safely withstand overvoltage conditions as they apply for the respective system rated voltages.

A-5. SWITCHING AND PROTECTIVE DEVICES AND CONNECTIONS

A-5.1 The surge capacitor is a protective device. As such it should have no fuses or isolating devices in its connection across the apparatus which it is expected to protect.

A-5.2 The surge capacitor in parallel with a lightning arrestor has to be connected in phase and ground a star connection in polyphase systems. The neutral of this connection must be grounded.

A-5.2.1 The requirements on connecting conductor cross-sections and earthing stations are given under safety requirements.

APPENDIX B

(*Clause* 9.1.2.1)

SAMPLING PLAN FOR CAPACITORS FOR SURGE PROTECTION

B-1. SCALE OF SAMPLING

B-1.1 Lot — In any consignment, all the capacitors of the same type and rating from the same batch of manufacture shall be grouped together to constitute a lot.

B-1.2 The number of capacitors to be selected from each lot shall depend upon the size of the lot and shall be in accordance with col 1 and 2 of Table 1.

B-1.2.1 These capacitors shall be selected from the lot at random. In order to ensure the randomness of selection, procedure given in IS : 4905-1968 'Methods for random sampling' may be followed.

B-2. NUMBER OF TESTS AND CRITERIA FOR CONFORMITY

B-2.1 The capacitors selected at random according to col 1 and 2 of Table 1 shall be subjected to each of the acceptance tests. A capacitor failing to satisfy the requirement of any of these tests shall be termed as defective. The lot shall be considered as conforming to these requirements if the number of defectives found in the sample is less than or equal to the corresponding permissible number given in col 3 of Table 1, otherwise the lot shall be rejected.

TABLE 1 SAMPLE SIZE AND PERMISSIBLE NUMBER OF DEFECTIVES

Lot Size	Sample Size	Permissible Number of Defectives
(1)	(2)	(3)
Up to 50	5	0
51 to 100	8	0
101 to 300	13	1
301 to 500	20	1
501 to 1 000	32	2
1 001 and above	50	3

APPENDIX C

(*Clause* 9.12.6, *Note* 5)

GENERAL REQUIREMENTS CONCERNING PARTIAL DISCHARGE MEASUREMENTS

C-1. Partial discharges in a dielectric give rise to current impulses when the capacitor under test is connected into a closed circuit. These current impulses produce voltage impulses across the terminals of an impedance forming part of the closed circuit. These should be applied to the input of a suitable measuring apparatus. This measuring apparatus must have the characteristics of a band-pass filter whose pass-band lies somewhere within the limits of 10 kHz and a frequency below the lowest natural frequency of the capacitor.

C-2. To obtain maximum sensitivity, it is desirable that the circuit of the test capacitor should be tuned to a frequency within the pass-band of the measuring apparatus. The output signal from this apparatus is taken as a measure of the ionization.

C-3. Calibration of the apparatus may be carried out by injecting repeated pulses of known magnitude into the circuit in any convenient manner, if necessary after substituting an ionization-free capacitor (of substantially the same capacitance) for the capacitor under test.

C-4. The sensitivity of the apparatus should be such that current impulses from the discharge of 50 pC, repeated each half-cycle of the supply frequency, can be clearly detected above the background noise.

APPENDIX D

(*Clause* 10)

GUIDANCE ON THE EFFECTIVENESS OF LIGHTNING ARRESTORS USED IN CONJUNCTION WITH THE SURGE CAPACITORS

D-1. The desired protection from surge voltages is obtained with the combination of an effective lightning arrestor and a surge capacitor, then with the surge capacitor alone.

D-2. The lightning arrestors shall be compatible with the combination of surge capacitors.

D-3. The surge monitor box having a current monitor is recommended for lightning arrestors at its service voltage given in **3.4**. The service monitor indicates the condition of lightning arrestor from time to time by enabling the measure of grading current.

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IS 11548 : 1986 SPECIFICATION FOR CAPACITORS FOR SURGE PROTECTION FOR USE IN VOLTAGE SYSTEM ABOVE 650 V AND UP TO 33 kV

(*First cover page, pages* 1 *and* 3) — Substitute '**1 000 V**' *for* '**650 V**'.

(*First cover page, pages* 1 *and* 3)— Substitute '**45 kV**' *for* '**33 kV**'.

(*Page* 4, *clause* **1.1**, *line* 4) — Substitute '45 kV' *for* '33 kV'.

(*Page* 5, *clause* **3.1**, *table, col* 3, *row* 5) — Delete 'and 0.25'.

(*Page* 5, *clause* **3.1**, *table*) — Insert the following at the end:

Highest System Voltage	*Surge Capacitors for Voltage Rating (Single Phase Rating)*	*Capacitance per Phase*
kV	kV	μF
40	45	0.125

(ET 29)

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